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2013

The Relationship of Previous Knee Injuries and Medial Knee Collapse During Squat and Jump Tasks in Division I Collegiate Female Athletes

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THE RELATIONSHIP OF PREVIOUS KNEE INJURIES AND MEDIAL KNEE COLLAPSE DURING SQUAT AND JUMP TASKS IN DIVISION I COLLEGIATE FEMALE ATHLETES

By

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B.A., Franklin College, 2010

Submitted in Partial Fulfillment of the Requirements for the

Master’s of Science in Education, Kinesiology

Department of Kinesiology

Southern Illinois University Carbondale

May 2013

RESEARCH APPROVAL

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A Research Paper Submitted in Partial

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Master's of Science in Education

in the field of Kinesiology

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April 9, 2013

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Dynamic knee valgus collapse, otherwise known as medial knee collapse or knee abduction, can be described as the combined motions of femoral internal rotation and hip adduction, tibial abduction, and ankle eversion (Joseph, M., Tiberio, D., Baird, J., Trojian, T., Anderson, J… Maresh, C., 2008). This frontal plane motion motion of the lower extremities can often be exaggerated during squatting, jumping, and landing tasks and has been linked to both chronic and acute lower extremity injuries, especially at the knee joint (Sigward, Ota, & Powers, 2008). Claiborne, Armstrong, Gandhi, and Pincivero (2006) report the importance of controlling frontal plane knee motion as large stresses are imposed on the involved joint. Stresses are placed on passive (ligamentous) tissue restraints and can increase anterior tibial translation causing excessive strain on the anterior cruciate ligament (ACL) (Claiborne et al., 2006).

When comparing female athletes to their male counterparts, there is a prevalence of a larger Q-angle, a difference in quadriceps to hamstring strength ratios, and overall weaker hamstrings (Beutler, Motte, Marshall, Padua, &Boden, 2009). Due to these anatomical differences, female athletes are more predisposed to acute knee injuries than males (Vauhnik, R., Morrissey, M.C., Rutherford, O.M., Turk, Z., Pilih, L.A., & Perme, M.P, 2011). Beaulieu and McLean (2012) report a possible link in young females between knee injury and increased angles of knee abduction during landing tasks. They also state that this increase in knee abduction may be due to landing tasks requiring altered hip kinematics, such as increasing hip adduction angles (Beaulieu & McLean, 2012).

The occurrence of dynamic knee valgus at time of injury during jump landing has been shown to increase the risk of acute knee injuries in females (Joseph et al., 2011). Beutler et al.

(2009) report that gender-specific differences can be found during athletic tasks such as cutting, jumping, and stopping. During jumping and landing tasks, it has been found that females will land with increased knee extension as well as greater knee valgus (Joseph et al., 2011). These differences in mechanics are described by Beutler et al. (2009) as particularly important pieces of information due to the highest occurrence of anterior cruciate ligament (ACL) injuries occurring during landing from jumping tasks.

After testing 2,753 United States Air Force, Army, and Naval cadets on landing techniques, Beutler et. al (2009) found that weaker hamstrings and gluteus medius strength deficits in females were important predictors of poor mechanics when landing from a jump. Similarly, Claiborne et al. (2006) discuss how both hip and knee musculature strength can affect the kinematics of the lower extremities during weight bearing activities and how there are differences between genders during these activities. For their study, 30 participants (15 men, 15 women) completed a series of single leg squats (SLS) while also testing isokinetic strength during knee flexion, knee extension, hip abduction, hip adduction, flexion, extension, internal rotation, and external rotation. Frontal plane knee motion was assessed during the SLS task, using a motion analysis system. It was reported that during a SLS task, knee flexion, knee extension, hip internal rotation, and hip abduction strengths were the strongest predictors of frontal plane knee motion. Due to significant negative correlations between knee valgus motion and these strength variables, it was determined that as strength in these motions increased, the degree of knee valgus in the frontal plane decreased, as well (Claiborne et al., 2006).

Nadler, S., Malanga, G., Solomon, J., Feinberg, J., Foye, P., & Park, Y (2002) describe how hip extensor and abductor musculature work to stabilize the trunk and hip during activities. As these muscle groups work together to stabilize the pelvis, any deficit in strength, in one or multiple muscles, may influence a person's mechanical function during activity (Nadler et al., 2002). In this study, the researchers tested the hip extensor (gluteus maximus) and abductor (gluteus medius) strength, using a dynamometer, of 236 NCAA division I athletes. Following athletes' routine pre-participation musculoskeletal and cardiovascular examinations, participants were questioned about their history of lower extremity injuries from the previous year. The researchers found that when looking at the ratio of hip abductor to hip extensor strength, there was a significant difference between athletes with and without a history of lower extremity injuries (Nadler et al., 2002).

Patellofemoral joint pain, also described as anterior knee pain, often will occur in those individuals who have undergone knee surgery, specifically ACL reconstructions (Morrissey, M., Drechsler, W., Morrissey, D., Knight, P., Armstrong, P., & McAuliffe, T., 2002). This common occurrence is believed to result from the type of surgery performed, specific kinds of rehabilitation exercises implemented, and/or poor hip mechanics caused by muscular weakness. It has been found that reconstructing the ACL from a patellar tendon graft can increase the frequency of anterior knee pain due to the graft being taken from that area of the knee (Sajovic, Strahovnik, Dernovsek, &Skaza, 2011). Another cause for patellofemoral pain in post-surgical cases is believed to arise from the type of rehabilitation exercises implemented. However, a study was conducted investigating the use of open kinetic chain versus closed kinetic chain exercises in early post-surgical knee rehabilitation. It was found that there were no significant differences between the type of exercises used and the frequency of anterior knee pain occurring (Morrissey et al., 2002). Crossley, Zhang, Schache, Bryant, and Cowan (2011) discuss how knee pain, specifically anterior knee pain, indicates the possibility of hip muscle dysfunction being present. When looking at the gluteus medius, that electromyography (EMG) activity was delayed in the participants with an indicated poor performance of a SLS task. These findings are important for treating anterior knee pain by strengthening hip abductor musculature to fix poor mechanics (Crossley et al., 2011).

The lack of hip abductor strength, specifically with the gluteus medius, can be linked to dysfunctions occurring in an individual's lower extremities. Previously discussed issues such as anterior knee pain and poor mechanical movement patterns can occur from deficits with the gluteus medius. Similarly, Fukuda, T., Rossetto, F., Magalhaes, E., Bryk, F., Lucareli, P., & Carvalho, N. (2010) discuss how the patellofemoral joint can be affected by poor hip motion. They state that previous researchers have found that individuals suffering from generalized anterior knee pain when completing weight-bearing tasks, have excessive femoral internal rotation which causes the patella to move laterally (Fukuda et al., 2010). They state that this excessive femoral internal rotation is caused by a generalized weakness amongst the hip abductors and lateral rotators.

Bellew, J., Panwitz, B., Peterson, L., Brock, M., Olson, K., & Staples, W. (2009) investigated acute hip abductor fatigue and how it affects the control of balance in females, specifically older adults. Although this study is specific to an older population, the material can be generalized to a younger active population. The researchers discuss how, during both functional and sporting activities, neuromuscular fatigue can cause changes to occur in an individual's ability to complete the tasks at hand. They also state that being able to properly activate the muscle during dynamic activities is extremely important, when it comes to the stability of the joints in the lower extremities. If an individual has a deficiency in being able to stabilize the joint (specific to muscle activation) during activity due to muscle fatigue, the individual will not be able to complete the task safely (Bellew et al., 2009). More specifically, Kernozek, Torry, and Iwasaki (2008) discuss neuromuscular fatigue and how this phenomenon may be linked to the occurrence of noncontact ACL tears in female athletes. The authors report that previous researchers discuss how ACL injury rates increase as the activity time increases and also as the season progresses. The aim of their study was to examine gender differences in both kinetic and kinematic changes of the lower extremities caused by neuromuscular fatigue. They found that females, when landing in the post-fatigue condition, had greater knee valgus than the males. They also reported that both genders, when fatigued, had landing profiles similar to those of a noncontact ACL injury mechanism (Kernozek et al., 2008).

The relationship between quadriceps muscle weakness and fatigue in ACL post-surgical individuals was investigated using EMG analysis by McHugh, Tyler, Nicholas, Browne and Gleim (2001). It was stated that lower EMG frequency content is associated with weakness within the muscle being assessed. They found that weakness in the quadriceps after ACL surgery was associated with muscle fatigue (McHugh et al., 2001). Although this research is helpful in determining a relationship between muscle weakness and fatigue within the quadriceps, there are still unanswered questions regarding other muscle groups. Do these findings hold true in other muscle groups such as the hip abductors, following an ACL reconstruction? It has been observed, that hip abductor fatigue is a cause for poor mechanics and medial knee collapse (Kernozek et al., 2008). According to McHugh et al. (2001), the cause for fatigue relates to a weakness within the muscle. So, does hip abductor fatigue relate to a weakness within this muscle group?

To determine the level of muscle activation, the use of surface EMG has been found to be a reliable instrument. Neumann and Hase (1994) used EMG to determine muscle activity within the hip abductors during walking tasks. They discuss how the hip abductor muscle group, primarily the gluteus medius, provides rotational stability during single leg support (Neumann and Hase, 1994). This muscle group, when activating properly, will work to prevent femoral internal rotation and is important since the motion of femoral internal rotation is one of the primary contributing motions causing medial knee collapse (Joseph, et al., 2008). More recently, Bolgla and Uhl (2005) used surface EMG to determine the activation of the hip abductors during a variety of rehabilitation exercises. They found that weight-bearing exercises produced more activation within the abductor muscles than non-weight-bearing (Bolgla and Uhl, 2005).

Neumann (2010) discusses how, during complex lower extremity movements, the hip adductors will be activated to control femoral movements such as hip adduction, internal rotation, and flexion. During this internal rotation, the antagonist muscle, gluteus medius (hip abductor and external rotator), will be working eccentrically to decelerate the movement (Neumann, 2010). Jaramillo, Worrell, and Ingersoll (1994) investigated hip musculature isometric strength and endurance following knee surgery and observed that both the hip abductors and adductors were equally affected the procedure. However, pre to post surgical measurements were not taken. Instead, the involved limb was compared with the noninvolved limb. Due to this discrepancy, it is difficult to determine if the deficits are due to surgery or if the weaknesses were present and equal prior to surgery (Jaramillo et al., 1994).

Yeow, Lee, and Hong Goh (2011) discuss how there is a lack of understanding when it comes to comparing energy dissipation between double and single leg landing tasks. They hypothesized that there would be a significant difference in energy dissipation between the tasks, in both the frontal and sagittal planes of motion. They aimed to investigate this topic in hopes of better understanding how energy dissipation may be related to increased knee injury risks (Yeow et al., 2011). It was found that during single leg landing tasks the frontal plane knee range of motion was significantly greater than during double leg tasks (Yeow et al., 2011). Crossley et al.

(2011) state that a SLS task is an efficient clinical screening tool of hip muscle function. However, it was also stated that the relationship between hip muscle strength and knee motion control was unclear (Crossley et al., 2011). Therefore, they aimed to investigate if those individuals who performed poorly on the SLS task showed a difference in gluteus medius activity. It was found that individuals who completed the SLS task poorly had delayed gluteus medius EMG activity, and they discuss how this poor hip muscle function can cause hip and/or knee biomechanics to be altered (Crossley et al., 2011).

When progressing someone back from an acute knee injury there are some key concepts that need to be incorporated into his/her rehabilitation program. With this type of rehabilitation the main goals that a clinician needs to focus on are decreasing muscle atrophy, increasing full range of motion, and preventing/decreasing anterior knee (patellofemoral) pain (Parker, 1994). Although the knee joint is the affected joint, a clinician needs to be able to look at the whole body as a kinetic chain and not just focus on only the joint involved. Many times, the joints above and below the involved joint, as well as the contralateral limb, will be affected. For example, Hewett, Di Stasi, and Myer (2012) report that young athletes undergoing ACL reconstruction have complaints of contralateral limb compensations, specifically from asymmetrical mechanical and neuromuscular control. It is known that those suffering from patellofemoral syndrome generally have poor mechanics, especially when it comes to excessive frontal plane motion at the knee joint.

Isolated hip strengthening may affect those suffering from patellofemoral pain. Dolak, K., Silkman, C., Mckeon, J., Hosey, R., Latterman, C., & Uhl, T. (2011) observed that participants completing isolated hip strengthening had a significant increase in strength and function and had less pain compared to the isolated quadriceps group after only four weeks of rehabilitation. Similarly, Khayambashi, Mohammadkhani, Ghaznavi, Lyle, and Power (2012) investigated how isolated hip strengthening effects pain levels and health status in females with patellofemoral pain. Similar to Dolak et al., Khayambashi et al. (2012) found that those participants who completed the hip-strengthening reported decreases in pain and overall improved health status. It is apparent that the implementation of hip strengthening in a rehabilitation program for an acute knee injury would help to decrease an individual's anterior knee pain (Hewett et al., 2012). Bolgla and Uhl (2005) also discuss how hip abductor strengthening is important in the rehabilitation process. They state that including this type of strengthening can help to improve knee mechanical dysfunctions. However, it is unclear whether clinicians are properly treating these injuries with the mindset of the body being one whole unit and not just focusing on the joint involved. More specifically, are clinicians properly strengthening hip abductors to prevent poor knee mechanics and future injury in those individuals going through an acute knee injury rehabilitation program?

Previous research has focused on hip abductor activity and knee kinematic motion as a predictor for an acute knee injury. However, little research has been completed on those individuals that have already sustained an acute knee injury. Therefore, the first purpose for this study is to investigate the relationship between previous acute knee injuries and medial knee collapse during squat and jump tasks in female collegiate athletes. Since previous research has compared the activity of hip abductors to adductors only isometrically, the second purpose of this study is to investigate the ratio of EMG activity between the hip abductors and hip adductors during squatting and jumping tasks. It is hypothesized that there will be a higher occurrence of medial knee collapse during squat and jump tasks in those individuals that have a previous acute knee injury. Secondly, it is believed that the ratio of EMG activity between the hip adductors and hip abductors will be higher in those athletes that have suffered a previous acute knee injury.

CHAPTER 2

METHODS

Recruiting Participants

All head coaches of female collegiate sports at Southern Illinois University Carbondale were contacted through email, requesting permission to contact athletes of their respective sports. If permission was given, then a roster with contact information was requested. Those athletes whose coaches provided contact information and permission were sent an email explaining this study and requesting their participation. Only volleyball athletes responded to the request.

Ten female (n=4 previous knee injury, n=6 no history of knee injury, mean age 20 +/- 2, mean height 1.78m, mean weight 73.75kg,) division I volleyball athletes were recruited to participate in this study. All participants signed a Human Subjects Committee approved informed consent prior to initiation of this study.

Inclusion/Exclusion Criteria

Inclusion criteria for participation was age between 18 and 24, female, currently a division I collegiate athlete, participation clearance of any injury by the overseeing medical staff, and willingness to participate in the study. Exclusion criteria included lower extremity surgery or traumatic knee injury within the last twelve months, pregnancy, and any physical injury/condition/disease that might affect participant’s ability to complete tasks.

Instruments

Motion Capture System

The Qualisys Motion Analysis System (using the Qualisys Track Manager (QTM) software) was used to capture the motion of participants during squat and jump tasks. Movements were collected with Oqus 100 cameras collecting at 100 Hz. The 14 mm reflective sphere sensors were placed bilaterally on the lower extremities on the posterior superior iliac spines (PSIS), greater trochanters of femurs, lateral knee joint lines, and lateral malleoli.

Electromyography System

The Motion Labs System MA 300, collecting at 1000Hz, was used to assess electrical activity within the skeletal muscle during the squatting and jumping tasks. A ground electrode was placed on the skin over the left iliac crest. The 10 mm^2pre-gelled Ag/AgCl electrodes were spaced 20 mm apart center to center. The common mode rejection ratio was (CMRR) > 100 dB at a 60Hz frequency, while the input impedence was >10M, with the bandpass filter set from 20-500 Hz with a gain of up to 1000. Six channels were used to collect muscle activity from the hip abductors (gluteus medius), vastus medialus oblique, and the hip adductors (adductor longus), bilaterally. Electrodes were placed in-line with the respective muscle fiber lines. Origins and insertions of muscles were used to determine their location. The gluteus medius originates on the outer surface of illium and inserts on the lateral surface of the greater trochanter of the femur; the midline between these boney landmarks were where electrodes were placed. The vastus medialus oblique originates on the medial side of the linea aspera of the femur and inserts on the tibial tuberosity via the patella and patellar tendon. The distal position of this muscle was where the electrodes were place. The adductor longus originates on the pubic tubercle and inserts on the linea aspera of the femur (Prentice, 2004).

Demographic Questionnaire

Participants were asked to complete a questionnaire regarding their demographics. This questionnaire included questions regarding gender, age, current medications, family and personal medical history, and orthopedic/musculoskeletal injury history.

Experimental Protocol

For a warm-up, each participant walked on a treadmill for 5 minutes at 0% incline. Participants were instructed to choose a moderate yet comfortable pace. Following the warm-up, participants were instrumented with electrodes placed over the specific muscle locations and the reflective spheres were placed on the lower extremities. A series of squat and jumping tasks were completed next. The order of the tasks were randomized to prevent the occurrence of a learning effect.

Squat Tasks

Each participant completed two different squat tasks and two different squat jump tasks (double leg and single leg). Each task was performed twice (each leg for single-leg).

Double leg Squat *(DLS):* Each participant was instructed to perform a two-leg body weight squat. They were instructed to have their feet hip-width apart, feet facing forward, with their hands on their hips. They were to lower their bodies into a squat as close to a 90 degree angle as possible. They were instructed to act as though they were sitting down into a chair (Heyward, 2006).

Single leg squat *(SLS):* Each participant completed two single leg squats on each leg. They were instructed to stand on one foot with their hands on their hips. Their stance foot was centered under their body with the foot directed anteriorly in order to balance on the one foot. They were instructed to squat down as close to 90 degrees as possible before returning to the starting position (Heyward, 2006).

Jump Tasks

Double leg squat jump *(DLSJ):* The participants were instructed to stand with feet hip-width apart and have their hands on their hips. They were told to squat down as close to 90 degrees as possible and then explode upwards into a jump keeping their hands on their hips. They were instructed to land with feet hip-width apart, and to ease back down into a squat (Prentice, 2004).

Single leg squat jump *(SLSJ):* Participants completed four SLSJs (two on each leg). They were instructed to stand on one foot positioned centrally under their body to balance. Again, their hands were on their hips and they were instructed to squat down as close to 90 degrees as possible. Then they were to explode upwards, keeping their hands on their hips, and jump as high as they could. They were then to land lightly, with the foot positioned under body to balance, and ease into a squat (Prentice, 2004).

Data Analysis

The kinematics data were low pass filtered with a fourth order Butterforth filter at 10 Hz. The kinematics data were used to determine the sagittal and frontal knee joint angles during each task. Sagittal knee angles were determined as anterior (x-axis) and vertical (z-axis) differences between the thigh and leg segments using a clinical joint nomenclature (ie., 180° = full knee extension). Similarly, frontal plane knee angles were determined using leftward-lateral (y-axis) and vertical (z-axis) differences for both right and left sides (180° = neutral knee position).

All surface EMG data were rectified and smoothed with a fourth order Butterworth filter at 10 Hz. The EMG data were then used to compile ratio data between the ipsilateral abductor and adductor muscles, respectively. To determine when EMG data collection was initiated and completed, kinematic data, specifically sagittal plane knee movement, was used. For flexion, the initiation of movement was the starting point and ended with peak knee flexion. Extension was peak knee flexion through the cessation of movement. This ratio was determined by using mean

EMG output for each of the movement segments for the abductors and adductors. Mean adductor output was divided by mean abductor output.

Due to the squat and jump tasks being complex movements to analyze, they were broken down into simpler movement segments. For the squat tasks there were two movements: flexion and extension. Flexion is the lowering of the body into the squat and extension is the standing back up. For the jump tasks, there were four segments: flexion1, extension1, flexion 2, and extension2. Flexion1 is the lowering of the body into the squat, extension1 is the exploding upwards into the jump, flexion2 is the landing and lowering back into the squat, and extension 2 is the standing up.

Statistical Analysis

The statistical analysis aimed to answer several questions; 1. Was there a difference between sides in the frontal plane knee angles? 2. Was there a difference between sides with adductor to abductor EMG ratios? 3. Was there a difference comparing history of knee injury to no injury in the frontal plane knee angles? 4. Was there a difference when comparing EMG adductor to abductor muscle ratios between history of injury to no injury? One-way analyses of variance (ANOVAs) were completed using SPSS (v.20) to test the independent variables (injury/not injury, DLS, SLS, DLSJ, SLSJ) and assess these questions. Alpha level was set at $p < 0.05$.

CHAPTER 3

RESULTS

Sagittal and frontal plane knee angles for a participant with a previous knee injury can be found in Figure 1. Sagittal and frontal plane knee angles for a participant without a previous knee injury can be found in Figure 2.

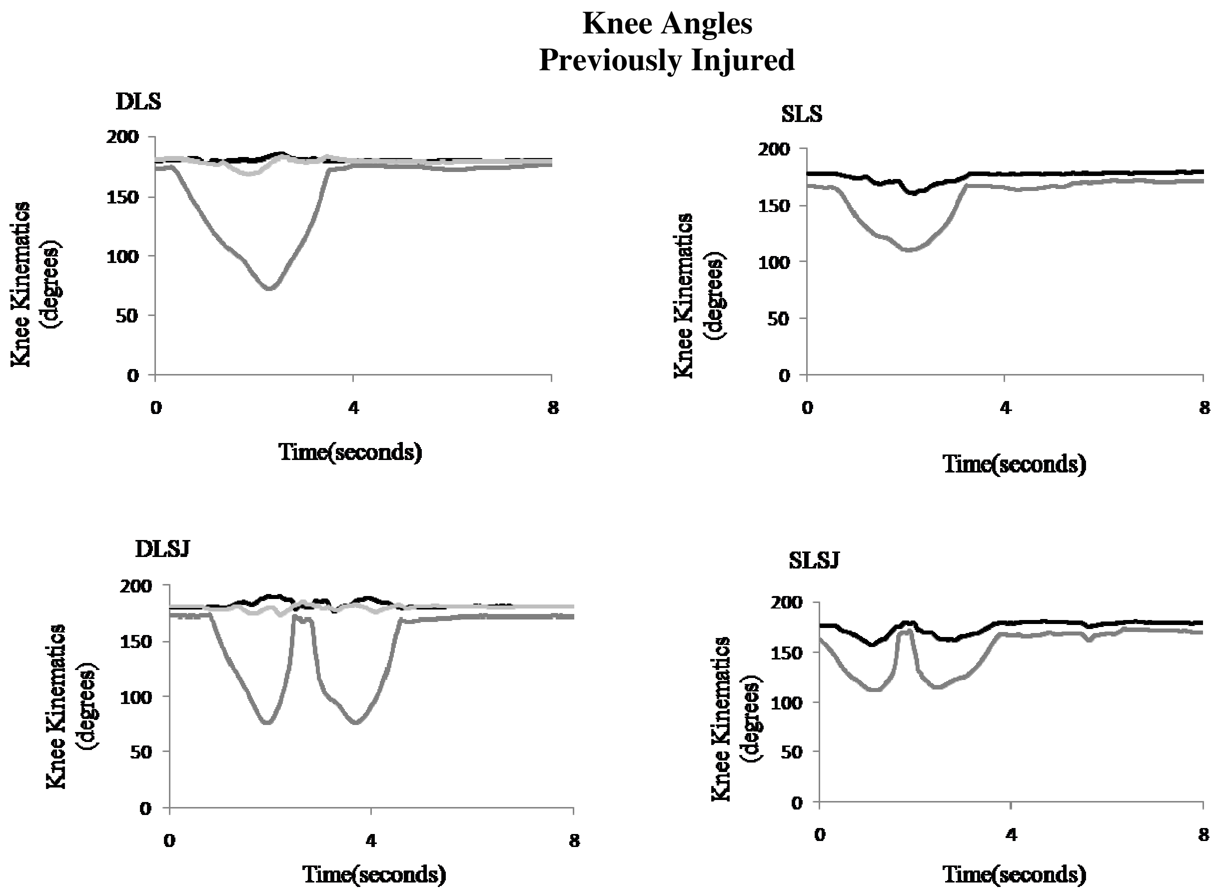

Figure 1. Sagittal (dark gray) and frontal (black and light gray) plane angles, previous injury DLS: Double leg squat, SLS: Single leg squat, DLSJ: Double leg squat jump, SLSJ: Single leg squat jump

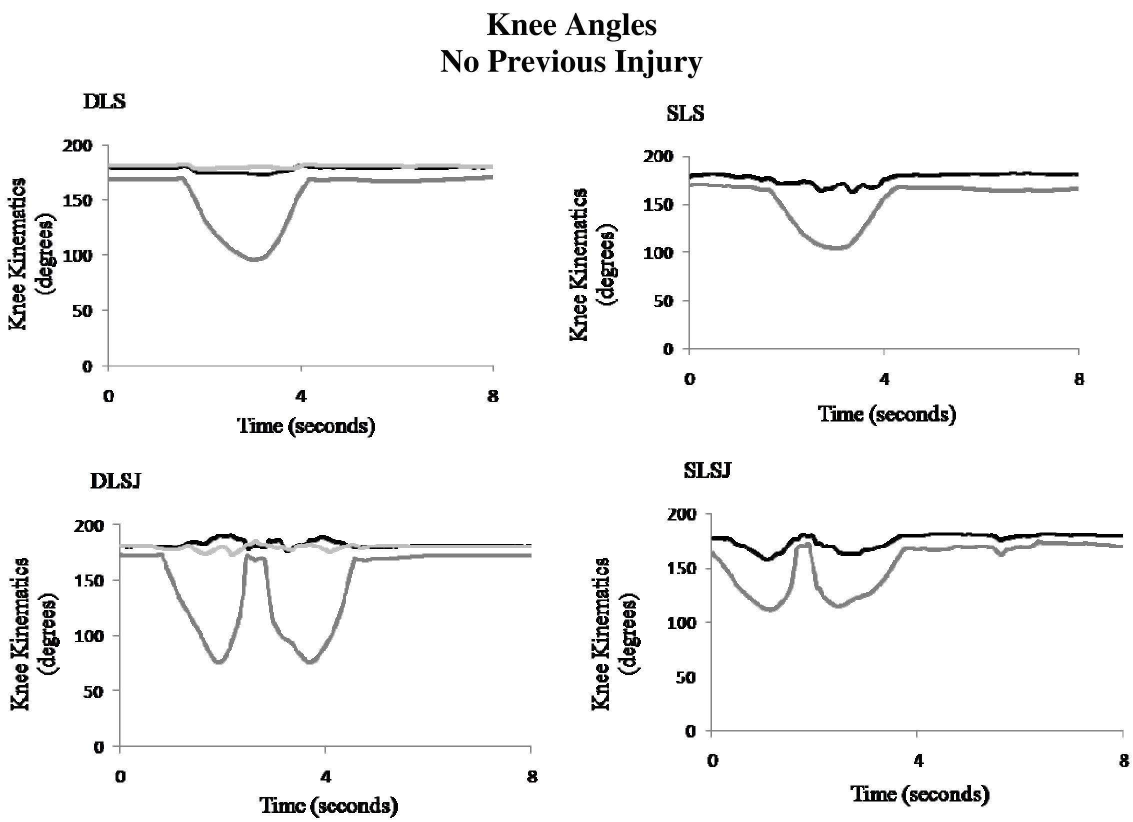

Figure 2. Sagittal (dark gray) and frontal (black and light gray) plane angles, no previous injury DLS: Double leg squat, SLS: Single leg squat, DLSJ: Double leg squat jump, SLSJ: Single leg squat jump

Frontal knee angle means and significance between sides can be found in Table 1. SLS during the extension phase ($p<0.004$) and SLSJ during the first flexion ($p<0.01$) showed a sig. difference between sides.

Table 1

Frontal Knee Angle Means and Significance Between Sides (L: Left, R: Right)

DLS	**Side**	**Mean**	**SD**	**p-value**	**SLS**	**Side**	**Mean**	**SD**	**p-value**
Kang flex	L	174.37	3.76	0.823	Kang flex	L	174.38	19.82	0.343
	R	169.7	4.95			R	169.7	9.02	
Kang ext	L	176.83	4.54	0.986	Kang ext	L	176.83	15.1	0.04*
	R	168.3	4.87			R	168.3	9.67	
DLSJ					**SLSJ**				
Kang flex1	L	180.02	3.25	0.448	Kang flex1	L	178.38	13.13	0.01*
	R	180.9	3.92			R	168.99	7.95	
Kang ext1	L	179.08	3.32	0.111	Kang ext1	L	173.18	9.88	0.202
	R	180.94	3.88			R	169.28	9.1	
Kang flex2	L	180.88	3.21	0.699	Kang flex2	L	178.09	6.65	0.709
	R	181.35	4.33			R	177.31	6.46	
Kang ext2	L	180.09	2.76	0.317	Kangext2	L	176.16	12.4	0.274
	R	181.2	4.06			R	172.7	6.33	

*Significant Difference (p<0.05)
DLS: Double leg squat, SLS: Single leg Squat, DLSJ: Double leg squat jump, SLSJ: Single leg squat jump

Frontal knee angle means and significance between injury history can be found in Table 2. No sig. differences were found between injury history for frontal knee angles.

Table 2

Frontal Knee Angle Means and Significance Between Injury (Y: Injury, N: No injury)

DLS	Injury	Mean	SD	p-value	SLS	Injury	Mean	SD	p-value
Kang flex	Y	177.39	4.9	0.37	Kang flex	Y	177.99	23.08	0.226
	N	178.95	4.21			N	170.55	12.88	
Kang ext	Y	178.5	4.75	0.706	Kang ext	Y	174.52	8.75	0.647
	N	179.21	4.69			N	172.08	14.21	
DLSJ					**SLSJ**				
Kangflex1	Y	179.72	4.04	0.522	Kangflex1	Y	178.41	17.82	0.207
	N	180.65	3.51			N	172.51	9.69	
Kang ext1	Y	180.36	3.41	0.767	Kang ext1	Y	166.31	9.47	0.105
	N	179.92	3.8			N	172.46	9.35	
Kangflex2	Y	182.23	1.23	0.355	Kangflex2	Y	174.23	8.17	0.09
	N	180.83	4.14			N	178.57	5.818	
Kang ext2	Y	181.54	2.1	0.42	Kang ext2	Y	171.79	6.92	0.403
	N	180.42	3.73			N	175.1	10.47	

*Significant Difference ($p<.05$)

SD: Standard Deviation, DLS: Double leg squat, SLS: Single leg Squat, DLSJ: Double leg squat jump, SLSJ: Single leg squat jump

Muscle EMG ratio (Add/Abd) means and significance between sides can be found in Table 3.

Muscle EMG ratio (Add/Abd) and significance between sides can be found in Table 3. Sig. ($p<0.039$) between sides was found during the extension phase of the DLS.

Table 3

Muscle EMG Ratio (Adductor/Abductor) Means and Significance Between Sides (L: Left, R: Right)

DLS	**Side**	**Mean**	**SD**	**p-value**	**SLS**	**Side**	**Mean**	**SD**	**p-value**
Mratioflex	L	2.56	24.77	0.154	Mratioflex	L	2.56	3.93	0.818
	R	2.86	11.26			R	2.86	4.27	
Mratio ext	L	2.94	24.35	0.039*	Mratio ext	L	2.94	4.23	0.339
	R	1.9	3.81			R	1.9	2.24	
DLSJ					**SLSJ**				
Mratioflex1	L	11.02	16.97	0.19	Mratioflex1	L	2.56	3.2	0.355
	R	5.01	10.88			R	5.36	12.97	
Mratio ext1	L	3.28	3.38	0.667	Mratio ext1	L	2.69	3.27	0.225
	R	2.72	4.68			R	1.7	1.49	
Mratioflex2	L	6.61	8.88	0.075	Mratioflex2	L	2.26	2.34	0.124
	R	2.61	4.07			R	1.38	0.92	
Mratio ext2	L	9.13	17.42	0.123	Mratio ext2	L	2.37	2.91	0.224
	R	2.82	4.16			R	1.51	1.1	

*Significant Difference ($p<.05$)

SD: Standard Deviation, DLS: Double leg squat, SLS: Single leg Squat, DLSJ: Double leg squat jump, SLSJ: Single leg squat jump

Muscle EMG ratio (Add/Abd) and significance between injury history can be found in Table 4. During DLS sig. was found for both flexion ($p<0.002$) and extension ($p<0.032$). DLSJ revealed sig. for the first flexion ($p<0.002$), the first extension ($p<0.02$), and the second flexion ($p<0.006$). Sig. during SLSJ was found for the initial flexion ($p<0.005$).

Table 4

Muscle EMG Ratio (Adductor/Abductor) Means and Significance Between Injury (Y: Injury, N: No Injury)

DLS	**Injury**	**Mean**	**SD**	**p-value**	**SLS**	**Injury**	**Mean**	**SD**	**p-value**
Mratio flex	Y	28.08	31.44	0.002*	Mratio flex	Y	4.25	5.09	0.233
	N	4.91	12.05			N	2.32	3.75	
Mratio ext	Y	21.08	28.98	0.032*	Mratio ext	Y	3.25	3.18	0.443
	N	5.81	13.39			N	2.21	3.44	
DLSJ					**SLSJ**				
Mratioflex1	Y	21.36	20.73	0.002*	Mratioflex1	Y	12.02	19.29	0.005*
	N	4.68	10.31			N	1.95	2.65	
Mratio ext1	Y	5.92	6.53	0.02*	Mratio ext1	Y	2.97	1.9	0.344
	N	2.27	2.85			N	2	2.69	
Mratioflex2	Y	10.59	10.94	0.006*	Mratioflex2	Y	2.51	1.07	0.231
	N	3.11	5			N	1.65	1.93	
Mratio ext2	Y	5.84	6.05	0.973	Mratio ext2	Y	2.1	1.23	0.828
	N	6.01	14.19			N	1.91	2.41	

*Significant Difference (p<.05)

SD: Standard Deviation, DLS: Double leg squat, SLS: Single leg Squat, DLSJ: Double leg squat jump, SLSJ: Single leg squat jump

CHAPTER 4

DISCUSSION

There were two main purposes of this study. The first purpose was to investigate the relationship between previous acute knee injuries and medial knee collapse during squat and jump tasks of female collegiate athletes. The second purpose was to investigate the ratio of EMG activity between the hip abductors and adductors during squatting and jumping tasks. It was hypothesized that there would be a higher occurrence of medial knee collapse during squat and jump tasks in those individuals that have a previous acute knee injury. Also, it was believed that the ratio of EMG activity between the hip adductors and abductors will be higher in those athletes that have suffered a previous acute knee injury.

To discuss the first hypothesis, the results must be examined in the specified individual movement segments as well as double leg versus single leg tasks. The findings do not support the first hypothesis that individuals who have suffered a previous acute knee injury will have a higher occurrence of medial knee collapse than those who have not. It was found that there were no significant differences between the groups, looking at frontal plane knee angles, during any of the movement segments. Ortiz et al. (2008) had similar findings when investigating knee kinematics during a drop jump landing and an up-down landing. Similar to this study, Ortiz et al. (2008) compared previously injured and non-injured female athletes. However, due to the differences in tasks being analyzed it is difficult to compare the studies. In the Ortiz et al. study (2008), for the single leg drop jump, the participant was to stand on a box and step off landing on one foot. The single leg up-down hop consisted of 10 consecutive single leg jumps onto a 20-cm step (Ortiz et al., 2008). Although the comparison between injury and no injury in the present study were not significant, this does not mean that medial knee collapse was not occurring in the participants. When looking at both Figure 1 and Figure 2, it is apparent that collapse is generally occurring equally between the two participants. This type of movement was consistent across all the participants.

The findings related to the second purpose of investigating hip adductor to abductor EMG ratios are more complex. It was hypothesized that this ratio will be higher in participants who have suffered a previous acute knee injury. This hypothesis was formed based on previous research findings by Nadler et al. (2002). When investigating hip abductor to hip extensor strength ratios, they found that there was a significant difference comparing athletes who had suffered a lower extremity injury previously to those who had no history of injury. To better understand the results, the findings needed to be examined with individual movement segments and testing conditions (double leg versus single leg).

When looking at the double leg tasks, both squat and jump, it can be determined that the results support the second hypothesis of this study. Significant differences were found for all the individual movement segments during these two tasks, except extension2 during DLSJ. This means that in the previously injured limbs, the hip adductors were firing at a higher rate than the hip abductors during each of the specified movement segments. Previously, Jaramillo et al., (1994) had opposing findings, stating that following knee surgery, participants had equal deficits in the hip abductors and adductors.

The single leg tasks, unlike the double leg, had only one significant difference after analyzing the data. During the SLSJ, flexion1 had a significant difference in EMG ratios comparing the injured to the non-injured. This means that as the previously injured participants lowered themselves into the initial squat prior to jumping, their hip adductor to abductor ratios were higher. However, this is not what was expected.. Based on Crossley et al. (2011), during single-leg squat tasks, participants showed signs of poor hip abduction function. These findings are opposing to the present study.

Although medial knee collapse was not significantly different comparing previously injured to non-injured participants, it was apparent that this poor mechanical movement was occurring in both groups. This common occurrence could be due to all the participants being female. Joseph et al. (2011) discussed how, when comparing genders, female athletes will typically have a higher incidence of knee valgus during landing tasks. When moving from a double leg task to a single leg task it would be expected for mechanics to change. Yeow et al. (2011) discussed how lower extremity energy dissipation is different comparing double and single leg landing tasks based on biomechanical differences. From the present study, EMG ratio data showed more significance with double leg tasks compared to single leg. This finding indicates that something must have changed from one task to the next; however it is difficult to determine what that change was based on the data gathered.

Future research is needed to better investigate medial knee collapse and hip abductor/adductor muscle function during squat and jump tasks. Focus should be placed on why double leg tasks showed signs of poor muscle function in the hip abductors, but not in single leg tasks. Also, more investigation is needed on frontal plane knee kinematics during these squatting and jumping tasks.

A limitation of this study is that all the athletes are from the same university. A delimitation of the study is that all the participants are division I athletes. Also all of the participants are female. Another delimitation is that all the participants were volleyball athletes and not from a variety of sports. This will make it difficult to generalize the results to the general public or other athlete populations.

CHAPTER 5

CONCLUSION

From this study, there are three main conclusions that can be made about medial knee collapse in previously injured female athletes. First, both previously injured and non-injured female volleyball athletes show signs of knee valgus during both squatting and jumping tasks. Second, there is no significant difference between non-injured and previously injured athletes when looking at the occurrence of this collapse. Finally, during double-leg squat and jump tasks, previously injured female volleyball athletes have a higher occurrence of poor hip abductor muscle function.

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Research Paper Title:

The Relationship of Previous Knee Injuries and Medial Knee Collapse During Squat and Jump Tasks in Division I Collegiate Female Athletes

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